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(54) Method for reducing the wear of the electrode in machine tools using electro-erosion.

(57) The method consists in providing the circuit with different power levels ; the tension of the first can be superior, facilitating the ionization of the channel and reducing the ionization delay. A circuit detects the ionization and starts some programmable counters, which count impulses supplied by the time base, the frequency of such impulses is higher then the one of the work impulses ; when the preselected count has been exceeded, the circuit transmits a conduction signal to the following power level, which supplies a stronger current impulse, with a certain delay with respect to the first, and so on. Consequently, the working current is built up in stairs ; this can be realized in one or more jumps so that the selected currents continue to increase progressively, varying at will the shape of the rising edge of the current impulse. This method reduces the wear of the electrode by at least 50 %.

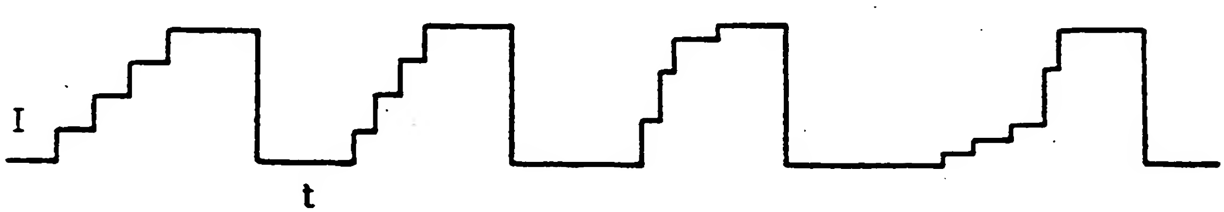

FIG. 10

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Method for reducing the wear of the electrode in machine tools using electro-erosion

This invention concerns a method for reducing the wear of the electrode in machine tools using electro-erosion.

Before explaining the object of this patent, we consider it necessary briefly to explain the process of electro-erosion, and then to present the improvements which will be expounded and which constitute the object of the invention.

It is known that the process of electro-erosion is carried out by making a series of electrical discharges jump between two conductors, one of them called electrode and the other part.

The purpose of the system is the faithful reproduction of the shape of the first on the second. It is widely used for making moulds, dies, wire-drawers, etc.

To carry out the erosion, both electrodes are connected to a source of current impulses, generally of rectangular shape, and both being submerged in a dielectric liquid. This liquid performs various functions: it acts as insulator, as refrigerant, and for attracting particles detached during the work.

The process of electro-erosion is brought about first and foremost by the heat effect of the electrical discharge, although there are also mechanical and electro-magnetic effects.

At the initial moment, an impulse of tension is applied to both electrodes, and if the electrodes are separated by a distance sufficiently small for the impulse of tension to overcome the dielectric resistance of the liquid, this ionizes, creating a small channel through which an electrical current of a determined value circulates. This impulse will produce a localized fusion on the part to be machined, leaving a small crater in it.

Each new impulse will repeat the process by which the electrode continues to reproduce itself in the part, leaving a cavity with the profile of the part.

It is necessary for the current to be pulsating so that each time a new channel opens, a new discharge passes, since if this were not the case, it would always be produced at the same point and the desired reproduction would not be achieved.

During the work, a series of residues proceeding from the fusion of the material are detached; they remain in suspension in the dielectric liquid, which should carry them away from the working zone.

If they are not eliminated, these residues have a pernicious effect, since the accumulation of them makes the electrical discharges become anomalous. When this happens, some of them tend to pass by the same channel and finish by producing a continuous discharge in the form of an arc with the consequent formation of a carbon.

The process also requires the impulses to be unidirectional, since in this form it has been seen that the wear of the electrode is assymmetrical with respect to the part, the wear being less in the electrode and more in the part.

The ideal would be if there were no wear at all in the electrode. Unfortunately, this is not the case in practice, and this is due to various factors.

The main objective of this patent, apart from other improvements, is precisely to reduce the wear of the electrode practically to half of the wear which now takes place in electro-erosion machines.

It is known that electro-erosion made a great advance in respect of wear and speed of mechanization when, instead of using systems based on relaxation circuits, the system of pre-established impulses of current was introduced.

The use of impulses made a great advance thanks to modern power transistors which make it possible to control very high current intensities and which, in addition, can work at considerable commutation speeds, making it possible to use sufficiently high frequencies.

One of the most suitable forms of making a transistor work to control strong currents is by using the so-called commutation system in which the transistor presents two clearly defined states: the off state and the state of saturation. This system has the advantage of high performance and little dissipation of heat in the commuting element, since tension and current do not coincide in this element at the same time.

The greatest losses in such a system are produced more or less exclusively at the moment of transition from one state to the other, so the attempt should be made to produce this transition in the shortest possible time. The shorter it is, the better the transistor will work and the smaller will be the losses in it, although naturally the type of load coupled to it also influences its working.

For a better explanation of the phenomenon, see fig. 1 which shows an impulse of current and in which we can see that the shorter are the "t" on and "t" off times, the less will be the dissipation in the transistor, i.e. what is claimed is that both sides will be as vertical as possibie, with the greatest attainable value of di/dt.

Returning to the process, we see that in fig. 2, an impulse of tension in open circuit is represented at (a), and an impulse of tension in working conditions at (b) and (c). Represented at (d) and (e) is the impulse of current corresponding to each of the above.

In open circuit, i.e. when the electrode and the

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part are separated by a distance greater than that of ionization, the impulse has the shape represented at (a). This impulse has had no effect, so that it is a lost impulse. In (b), the impulse of tension already represents a distinct shape since in this case both electrodes will be at the correct distance, and therefore the ionization will have been produced. The time "t" on is the time of ionization after which the impulse of current would have circulated between both electrodes. At (c) we see another impulse of tension which presents a longer time of ionization than the previous one.

This delay in the ionization is completely random, although by increasing the tension in the casting mould it is possible to reduce this time considerably. If the state of ionization is lengthened, we see that the impulse of current is narrower and circulates for a shorter time.

Since, in addition, the energy of the impulse is proportional to its area, the material torn out and thus the crater left will be different in both cases.

In practice, there are two fundamental systems: the isoenergetic impulses and the heteroenergetic impulses. The former have an equal time of duration, while the latter have completely irregular times.

Between two consecutive impulses of current; there must always be a pause, the purpose of which is to allow the dielectric liquid to recover its insulating properties so that it can close the channel of conduction in the mould, and in this way make it possible to re-initiate the process at another different point of the part.

In practice, we try to make the pause as short as possible so that the frequency of recurrence can be as high as possible, in order to increase the productivity of the removal of material. However, either because there are residues between electrode and part, or because hot points are produced if the pause is excessively short, there are times when various consecutive impulses travel through the same channel, with the result that there is no de-ionization and the process degenerates into a continuous electrical arc, damaging the part and the electrode and forming a carbon which could have fatal consequences and which must be eliminated by the worker himself.

One of the procedures used to avoid this phenomenon is to give a periodical to and fro movement to the electrode, so that when the electrode moves away, it is easier to evacuate the residues. However, since the accumulation of residues depends on various factors such as the speed of working, the geometry of the part, the depth of the cavity, etc., it is practically impossible to optimize the cleaning cycles so as to avoid the problem completely, unless this is done at the price of poor performance by the machine.

A system for being able to detect the instant at which these abnormal discharges are going to be produced is by observing the peak tension of ionization, since before the degenerative phenomenon is produced, it is possible to observe that these peak tensions diminish or even arrive at total cancellsion, so this makes it possible to take pertinent measures to attack the problem before it worsens.

The system of temporary withdrawal of the electrode also has another disadvantage in that it is totally independent of the conditions of work. Frequently the electrode withdraws when it is needed, and fails to withdraw when it is not needed. Giving this alternating movement to the electrode brings about a spectacular reduction in the performance of the machine, since during these to and fro intervals, the machine does not erode. So if we add up these fractions of time lost at the end of a working day, the total ineffective time can be considerable, with a corresponding coniderable loss of productivity.

In all electro-erosion machines, the pause times are totally independent of the impulse times, so that at each new regulation of the impulse time, it is necessary to regulate the pause time to obtain good stability and performance in each new regime selected.

This will become clearer if we take an example. Supposing that we have selected as first work pass an impulse time of 100 microseconds and a pause time of 10 microseconds. Once the work at this speed is finished, we want to change to an impulse time of 10 microseconds. If we do not modify the pause, we shall see that, while in the first case we had an impulse to pause ratio of 10 to 1, in the second case we would have a ratio of 1 to 1, i.e. of 50 %, with which the performance obviously cannot be the same.

In the circuit developed in this patent, the ratio is maintained constant, since the pause time is always expressed as so many percent of the impulse selected.

Let us now go on to analyse the wear suffered by the electrode. In this respect, the inventor has been able to find that almost 50 % of the wear suffered by the electrode takes place at the moment of establishing the channel of ionization, and the shorter the time of transition between break and conduction, the greater is the wear produced. This led him to frame the hypothesis that at the moment of initiating the discharge, the channel is infinitely small, and if a very high current circulates in it, the resulting density of current is very high. With the passage of time, the channel progressively widens, thus distributing the same current over a greater area, so that the density of the current logically diminishes. However that may be, one thing is certain: the more vertical the slope of

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the rising side of the current impulse, the greater the wear, i.e. the wear is in a certain manner proportional to the ratio di/dt.

Moreover, the initial peak of current can be reinforced by the fact that, due to the parasite capacities present in the circuit and capacity proper to electrode and part, if these capacities are loaded before the ionization, they discharge their energy at the moment the ionization is produced, with an initial energy at 1.2 Cy^2.

Since this necessary reduction of slope in order to avoid wear is incompatible with good commutation of the power transistors, since its dissipation could go outside the safety area, a method has been established which complies with both requirements.

So a method has been invented which does not present these disadvantages and, in addition, makes it possible to give time to the channel to widen.

The method consists in giving the generator of impulses various stages of power, distributed in weighted form in respect of the intensities of current referred to, of which the first could be supplied at the same tension as the others, or at a higher tension than the others, with which the initial ionization could be facilitated.

The different stages of current are disposed in such a way that the discharge of each of them is produced sequentially and preferably regulated by a code determined to be able to produce the whole range of necessary values of current, with a minimum number of them, such as, for example, the BCD code.

The interval of time between each discharge of the stages is, in the same way, variable at will, so as to be able to produce the desired delay between each one of them.

The first step of power supplies an impulse of current the value of whch should be equal to or slightly more than the intensity of current of maintenance of the discharge, and always less than the working current selected. It should be noted in passing that the maintenance current is the minimum value of intensity, below which the discharge of each impulse is made unstable and its establishment unpredictable.

In the system developed, once the ionization is initiated, a circuit detects that this is the case and sets off a programmable counter which begins to count impulses proceeding from the time base, the frequency of which is much higher than those of the working impulses, and once the preselected count has been reached, the circuit gives a signal of conduction to the following stage of power, which supplies an impulse of current stronger than the previous one, with a certain delay in respect of the first. The third stage will be connected at the end of a certain time after the second has been connected, and so on.

In this way, we make it possible for the preselected current not to be established instantaneously at the moment of ionization, but in a spaced-out form, thus giving sufficient time to the channel to widen to a sufficient degree to let the strong impulse pass.

We can see that this spacing out can be made in various jumps so that the selected currents increase progressively until they arrive at the desired peak value, and from that moment onwards, the impulse continues normally.

So what is claimed is the power to vary the slope of the rising side of the current impulse step by step, the breadth of each step being a function of the time and the height, and since a function of the current varies each one of these parameters, it is possible to achieve an infinite range of shapes of the rising side of the impulse of working current, thereby giving it the form most suitable for reducing the wear of the electrode to its minimum value. Fig. 10 shows different forms of the rising side of the impulse.

We have found with this method that the wear of the electrode diminishes by practically 50 %. This is of the utmost importance, mainly in production involving fine relief work in which the cost of the electrode can represent an important item. Moreover, with this method, the small amount of wear is much more uniform and regular than with the present method, since it is precisely on sharp edges that the greatest wear is produced.

With this method, the transistors can always work with perfect commutation, permitting unlimited adjustment in the breadth and height of the step in question.

As the initial intensity is relatively weak, and therefore it is not practical to carry out an infinitesimal stepping, this first stage of supply can be equipped with means for varying the slope of the rising side of the current, taking especial account of the fact that in spite of what has been said about the dissipation of power, and given that in this stage the intensity is low, it would not therefore present problems of heat dissipation.

It is obvious that if 50 % of the wear of the electrode takes place in the rising side of the current impulse, the wear will be in direct relation to the number of impulses or to the frequency, and this is confirmed in practice, since the wear is greater in the higher frequency reigimes, which are precisely those used for finishing work, ie. precisely those in which the wear is most inopportune.

The method can be applied to any system for producing impulses, whether or not the impulses are isoenergetic; if they are not, however, there could be a considerable loss of performance in the

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machine, since if the time of ionization is considerably prolonged, the strong current impulse could fall outside the period of duration of the impulse, i.e. during the pause, which would mean that these impulses would be irremediably lost and therefore would contribute nothing to the useful work.

In the same way, the stepping can be produced in the falling side of the current impulse, which would make it possible to obtain an additional reduction of the wear, albeit a less significant one, since in consequence a small inversion of the current takes place, which may be produced when the instantaneous impulse of strong intensity is cut, there being - as there always are - parasite inductances in the circuit.

For greater clarity, we explain one of the possible practical implementations of the system.

In fig. 3 can be seen a block diagram in which A represents the general source of supply, B an oscillator circuit, C a decision logic, D the power amplifier, E the servo activating the electrode, F the electrode and G the part to be worked.

Let us now look at the working of each of them, block by block. Starting with block A: this consists of a series of supply tensions with their transformers, rectifiers and filters, well known to technicians in this field, so that we need not here go into more detail on them.

Block B is shown in fig. 4, and in it we see that b_1 represents a clock generating impulses with a frequency much higher than that of the working impulses of the machine. It will preferably be a quartz crystal clock, so as to guarantee good precision and stability.. We will suppose that this clock works at a frequency of 100 MHz.
The impulses proceeding from the clock enter block b_2 which is a frequency divider composed of a fixed division unit of value 100 and a unit that can be programmed from outside by means of the preselectors pr, or via a computer. This divider constitutes the generator of pause times. The impulses leaving block b_2 pass to block b_3, consisting of another programmable frequency divider, and this is the one which generates the impulse times of the working current. The output from this block is applied to a bistable circuit (b4) which changes state with each impulse that reaches it. Its output arrives a block b1 in such a way that in each of its states it selects alternately the fixed counter or the programmable counter.
Let us suppose that an impulse time of 120 microseconds has been selected, and a pause time of 10 % of the impulse. Starting with a frequency of 100 Mhz, whose period is 0.01 microseconds, we enter a signal of these characteristics at the divider b_2. If the signal proceeding from the bistable is a 1, in that case a fixed counter of value 100, for example, will be selected, and the output of this divider will therefore be a signal whose period will equal 0.01 x 100 = 1 microsecond. This signal, applied in turn at the divider b_3, which is programmed, let us suppose, at 120 microseconds, will give an output of 120 x 1 = 120 microseconds which, when it arrives at the bistable, will cause it to change state to give an output equal to 0 with which the divider b2, which was dividing by a fixed value of 100, will now divide by the programmed value which could, for example, be 10, which would give us 0.01 x 10 = 0.1 microseconds at the input of divider b_3 which is still programmed at 120. So at the output of this divider, we will now have a signal of 0.1 x 120 = 12 microseconds, which is what we were aiming at. This signal will again commute the bistable b_4, which will return to its state 1. The output signal now obtained will be as that of fig. 5.

In the divider b_2, it has also been foreseen that, by means of an external signal, it is possible to vary the factor of division for the purpose of widening the pause time when the working conditions are anomalous, and in this way we can avoid the formation of carbons between electrode and part.

This can be a single signal giving a fixed and pre-established pause width, or it can preferably be variable in shape, so that if the problem has not been solved with the first width, the following anomalous impulse produced will increase the factor of division by a certain value, and so on at each new incorrect impulse.

This progressive widening of the pause is in itself capable of preventing the formation of arcs, but in this circuit we have also provided an interrelation between the width and the control system of the servo, so that when the pause width is produced, as the average electrode/part tension diminishes progressively, this reduction is picked up by the comparator of the servo control circuit which "sees" a reduced tension and "gives" the order to open up the space between electrode and part progressively, and proportionally to the reduction of the electrode-part tension.

If the widening continues, a second comparator, which is adjusted at a higher level, gives the order to withdraw the electrode rapidly for cleaning the space between electrode and part. If for any reason this rapid withdrawal does not take place, it also emits a sigal which inhibits the production of impulses of strong current, so that it is practically impossible for an arc to be produced.

Both divider b_3 and b_2 are also provided with an asynchronous entry by which it is possible to reload the counters at any moment, reinitiating the count from that moment onwards, and in this way it is possible to obtain an impulse time that is perfectly controlled in breadth.

This signal arrives at the counters from the

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moment at which the detector circuit, which will be described below, has detected that the ionization has been produced.

We now go on to describe the discriminator block for working conditions (C), shown in fig. 6. In this we see that VC1, VC_2 and VC are dynamic comparators of the level of ionization tension. Each of them is adjusted at the suitable detection value. Their detection is made impulse by impulse, so as to obtain a total real-time monitoring of the working conditions.

The comparators VC4 and VC5 measure the average working tension, or they can also be accumulators recording the number of anomalous impulses as a function of the time, or also digital comparators which record the correct impulses that should be produced and those that actually are produced.

All the comparators have an adjustable level of comparation which, in the case of VC_5 can have an outside control for making the adjustment manually if desired.

In the block VC_6 is included the comparator of tension VC_1 and a logic which converts the level of tension compared into a synchronization signal which is applied to the frequency dividers b_2 and b_3 of the oscillator block, which re-initiates the count of impulse time from the instant in which ionization is produced, according to the time diagrams of fig. 7, in which diagram S_1 represents the electrode-part tension, and in it we can see the different times of ionization "t" ion 1 and "t" ion 2. V comp. represents the level of comparation of the comparator VC1.

At the output of comparator VC1 (signal S_2) appears only the time of ionization of diagram S_1, and it represents the tension which has been able to cross the threshold of the level of comparation V comp.

From the signal S_2 is extracted the information useful at the beginning of the ionization, which is converted into a signal (S_3) suitable for modifying the frequency dividers of the oscillator in such a way that the counters of the divider chains b_2 and b_3 re-initiate their count at the instant of receiving this signal, obtaining a result in accordance with diagram S_4, the duration of each impulse is proportional to the delay there has been in the time of ionization of each one of them, and equal to the sum of the delay in ionization and the time of the working impulse. As can be seen, with this system, we have succeeded in giving the impulses of working current an equal breadth, independently of the delay there may have been in producing ionization, and they are equal to the programme value tp. See diagram S_5.

The delay circuit (block C_7) includes the comparator VC_2, a logic, and some output stages, preferably optocoupled, which are directly attached to the power stages.

The comparator of this circuit detects, like the VC_1, the level of ionization tension, and its output is applied to a delay generator circuit, to which is also applied the output of the general oscillator. With both inputs, and via some bistables and a frequency divider chain, some outputs are generated, out of phase with one another, according to the time diagram of fig 8 in which, for greater clarity, we show only two outputs which is the minimum necessary for the system to work.

These diagrams show two inputs E_1 and E_2 which correspond respectively to the signal of the oscillator and to the signal proceeding from the electrode-part. The signal S_6 is the output of the comparator and corresponds to the delay in ionization. The signals S_8 and S_9 correspond to the output of the bistables, and S_{11} is the output signal of the frequency divider.

The output S_7 is a faithful reflection of the signal of the oscillator which, preferably via an optocoupler, as we said above, is input into the stage generating the impulse of weak current of the supply circuit of the ionization.

The output S_{10} is out of phase with S_7 which is the sum of the programmed delay plus the time of ionization. This output, via another optocoupler, is input into the following stage of strong current. This means that the signal S_7, amplified in the stage of weak intensity power, intiates the discharge with an ionization time "t" ion 1 according to the signal E_2.

In the instant of producing the ionization, the step of current of value Ia shown in fig. 8, graph I_s, is initiated in the same way, starting the count to produce the desired delay in the frequency divider chain included in this block.

When this time has passed, this divider chain emits a signal S_{11} to one of the bistables of the circuit which, on changing state, generates a signal S_9, and the optocouplers mentioned above give the signal S_{10} to the amplification stages of strong current of value Ib of the graph Ip. (fig. 8).

The result obtained is that the total duration of the current impulse is Tp = + Tf, i.e. weak current during the time initiated by the channel, and strong current during the time Tf, which is the rest of the working impulse.

With this circuit configuration, by simply cancelling the signal S_{10} by means of an appropriate logic, we inhibit the impulses of strong current, leaving only those of weak intensity which, moreover, are produced with a pause of greater than normal width, so that they are continuously exploring the state of the gap.

While the anomaly persists, there will be broad pauses and - arriving at the extreme case - there will be no impulses of strong current, thus avoiding

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the formation of carbons. When the gap returns to normal conditions, the machining impulses of strong intensity will be re-established by removing the inhibition of the signal S_{10}.

The practical effect this produces is reflected in the signal Ip (fig. 8) in which we observe that the impulse of current is stepped in the rising side. The small stepping corresponds to the initial impulse, and the large stepping to the power impulse.

The pause widening system block C_8 includes the comparator VC_3 and a decision logic.

The comparator analyses the level of ionization tension of each impulse signal S_{13}, generating an output signal S_{14} in cases where it is superior to the level of comparation.

To the logic circuit, we input the signal from the comparator, and its output is applied to the divider B_2 of the oscillator block, supplying it with the value of the factor of division, which will be t0 if it is taken from the pause preselector, or t_e, with a value superior to t_o, which will produce a longer pause. The decision between one or the other will depend on the comparator, according to the level of comparation of VC.

The logic circuit acts as follows: a bistable goes into one of its two states at the beginning of each impulse arriving at it from the oscillator (X), and changes state with the descending side of each impulse of ionization via the comparator (Y). See fig. 9.

If an anomalous impuse is produced ("h" in the graph S_{13}) the bistable remains during the whole of the cycle in the first state. The impulse Z which should have appeared if the impulse had been normal, fails to appear, and the pause is prolonged in consequence. This signal from the output of the bistable is the signal that decides between t_o and t_E.

Therefore the circuit continues to suppose that the following impulse is going to be anomalous, and consequently programmes a longer pause, but as soon as the ionization side characteristic of normal impulses appears, the circuit switches over and programmes a normal pause, doing so while the current impulse is taking place.

The circuit C_9 is the one responsible for producing the signal for the withdrawal of the servo, and consists of a medium tension comparator VC_4 and of a logic by means of which a signal is sent interrupting the work impulses and thus leaving the electrode and the part without tension; at the same time, another signal is sent to counters for them to record the impulses emitted by an encoder coupled to the servo. When then counters arrive at a predetermined number, the servo signal is inverted, and the servo begins to approach the part, at the same time as the counters begin to deduct. All these operations are completed at high servo velocity, in both withdrawal and approach, but when the counters reach a certain value in their deduction, they emit a signal which orders the servo to change to its slow speed. This allows the operation of cleaning to be completed as quickly as possible and also avoids the electrode, in its new approach to the part, going too far and being flattened against the part by the inertia effect of the system.

The circuit C_{10} is a servo regulation circuit and consists of a tension comparator and a differential amplifier which supplies an output of ± 10V capable of controlling a servo-valve, if the servo is of the hydraulic type, or a speed regulator with four quadrants if the servo is of the electro-mechanical type, with a DC motor, or a tension- frequency converter if the motor is of the step by step type.

Block D is a power amplifier composed of transistors working in commutation, in which it is possible both to use both bipolar transistors and MOSFETS, although the latter are preferable in view of their characteristics of high commutation speed, low control power, absence of second break, etc, these advantages being already known in the state of the art.

The invention, in its essentials, can be put into practice in forms other than those shown in detail in the description, to which the protection of the patent would also extend. Thus the invention can be implemented by the most suitable means, while still being included in the spirit of the claims.

Claims

1. Method of reducing the wear of the electrode in machine tools using electro-erosion, characterized by the fact that the circuit controlling the electrical discharges between electrode and part to be mahined comprises a series of power stages generating current impulses, preferably transistorized, which are distributed in weighted form in respect of values of current intensity, and can be connected in a sequential manner, preferably codified and synchronized by pulses from a clock, to produce successively incremental values of current, in such a way that these successive values of current are retarded in time so as to obtain a rising side of the impulse of current in a stepped form, in which the width of each step is a function of time and the height a function of the current, making it possible to obtain an infinite range of slopes and/or curves in this rising side of the current impulse, with which a minimum of 50 % of reduction in the wear of the electrode can be achieved.

2. Method of reducing the wear of the electrode in machine tools using electro-erosion, according to claim 1 characterized by the fact that the form of work of the stage of strong current, or

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stages if there are several, can be joined or stepped from the moment of receiving the delaying signal in respect of the first stage of weak current.

3. Method of reducing the wear of the electrode in machine tools using electro-erosion, according to claim 1, characterized by the fact that the disconnection of the stages of strong current can be made instantaneously, or by steps in the descending side.

4. Method of reducing the wear of the electrode in machine tools using electro-erosion, according to claim 1, characterized by the fact that the first impulse of weak current can continue working once the impulses of higher current are established, or can be suppressed during this operation, since the channel has already been established.

5. Method of reducing the wear of the electrode in machine tools using electro-erosion, according to claims 1 to 4, characterized by the fact that the first power stage, supplied by the initial supply impulse, includes means of varying the rising slope of the current impulse.

6. Method of reducing the wear of the electrode in machine tools using electro-erosion,, according to claims 1 to 5, characterized by the fact that the system of delay between the impulse of weak current and the impulses of strong current is applied to energy accumulation circuits, the accumulator of lower energy discharging first, and subsequently those of higher energy

7. Method of reducing the wear of the electrode in machine tools using electro-erosion, according to claims 1 to 6, characterized by the fact that it has a level comparator circuit with the task of continuously monitoring, impulse by impulse, in real time, the production of ionization, and in this case sending a recharge signal to counters controlling the impulse time, re-initiating the count from that moment onward, obtaining current impulses of equal energy.

8. Method of reducing the wear of the electrode in machine tools using electro-erosion, according to claims 1 to 7, characterized by the fact that it has a second comparator circuit monitoring the existence of ionization current between electrode and part to be machined, causing the pause time to be prolonged when it foresees that the impulse will be anomalous, then passing to the state of normal pause during the work impulse, by changing state, by means of the descending side of the ionization impulse.

9. Method of reducing the wear of the electrode in machine tools using electro-erosion, according to claims 1 to 8, characterized by the fact that a continuous series of anomalous impulses causes the prolongation of the pause time, the average value of the tension between electrode and part being reduced, and being detected by the servo regulator comparator making the servo withdraw rapidly, detecting the lower level and switching over to the rapid withdrawal of the servo.

10. Method of reducing the wear of the electrode in machine tools using electro-ersion, according to claims 1 to 9, characterized by the fact that if the servo - and consequently the electrode-failed to withdraw, the pause time would be increased step by step until the appearance of a signal inhibiting the stages of stronger current.

11. Method of reducing the wear of the electrode in machine tools using electro-erosion, according to claims 1 to 10, characterized by the fact that it has a circuit which will produce pause times which are percentages of the impulse time, maintaining a constant relation between both.

12. Method of reducing the wear of the electrode in machine tools using electro-erosion, according to claims 1 to 11, characterized by the fact that this system is also applicable to control by means of a commuting element in parallel with the load, or any combination with the other in series.

13. Method of reducing the wear of the electrode in machine tools using electro-erosion, according to claims 1 to 12, characterized by the fact that it has a comparator circuit of the average level of the tension between electrode and part to be machined, which gives a signal for the withdrawal of the electrode when the level falls to a value lower than that foreseen, which would be an indication of anomalous discharges.

14. Method of reducing the wear of the electrode in machine tools using electro-erosion, according to claim 13, characterized by the fact that the signal for the withdrawal of the electrode sends an order to the servo activating the electrode and at the same time sets going a counter chain which records the impulses sent from the servo in its withdrawal movement via an encoder, so that when a certain count is reached, the servo receives an inverse signal, starting the count in the opposite direction, or deducting, but before it reaches zero, it connects the servo with reduced speed, avoiding the electrode hitting the part.

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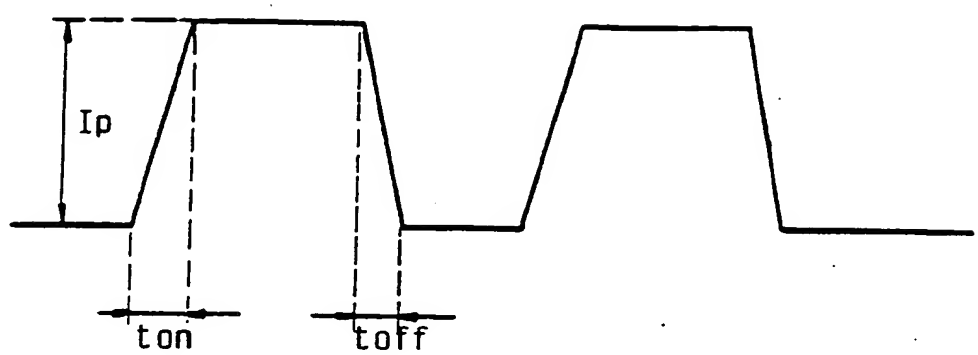

FIG. 1

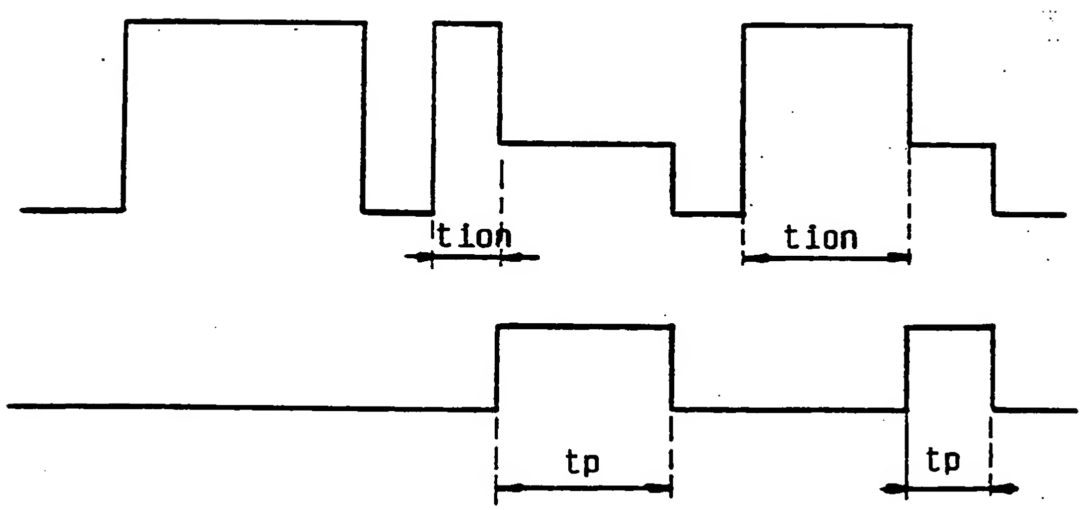

FIG. 2

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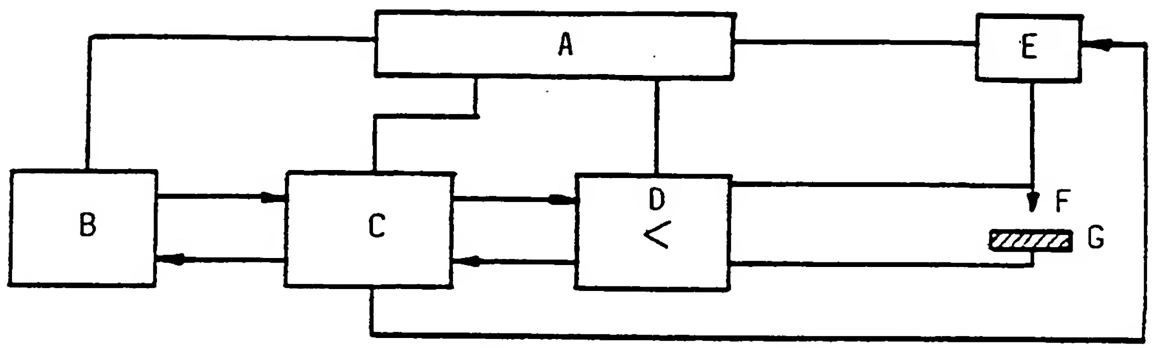


FIG. 3

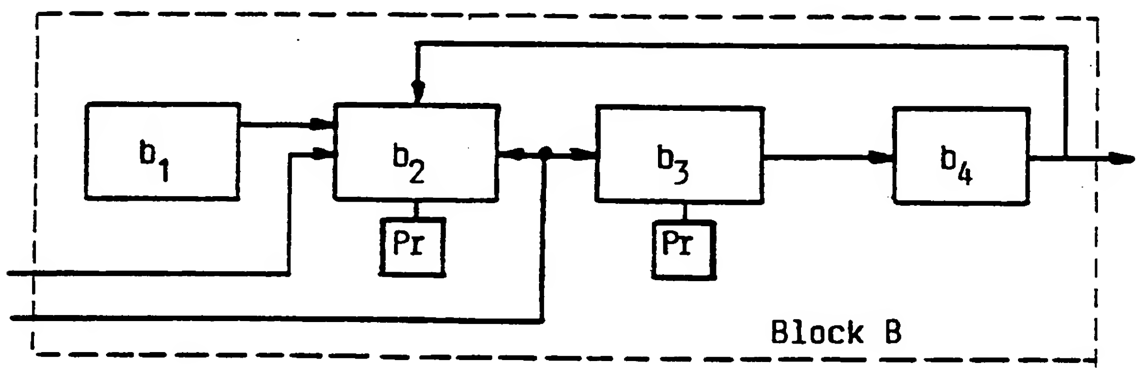


FIG. 4

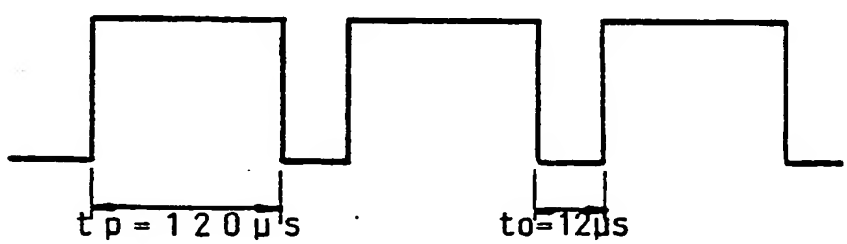
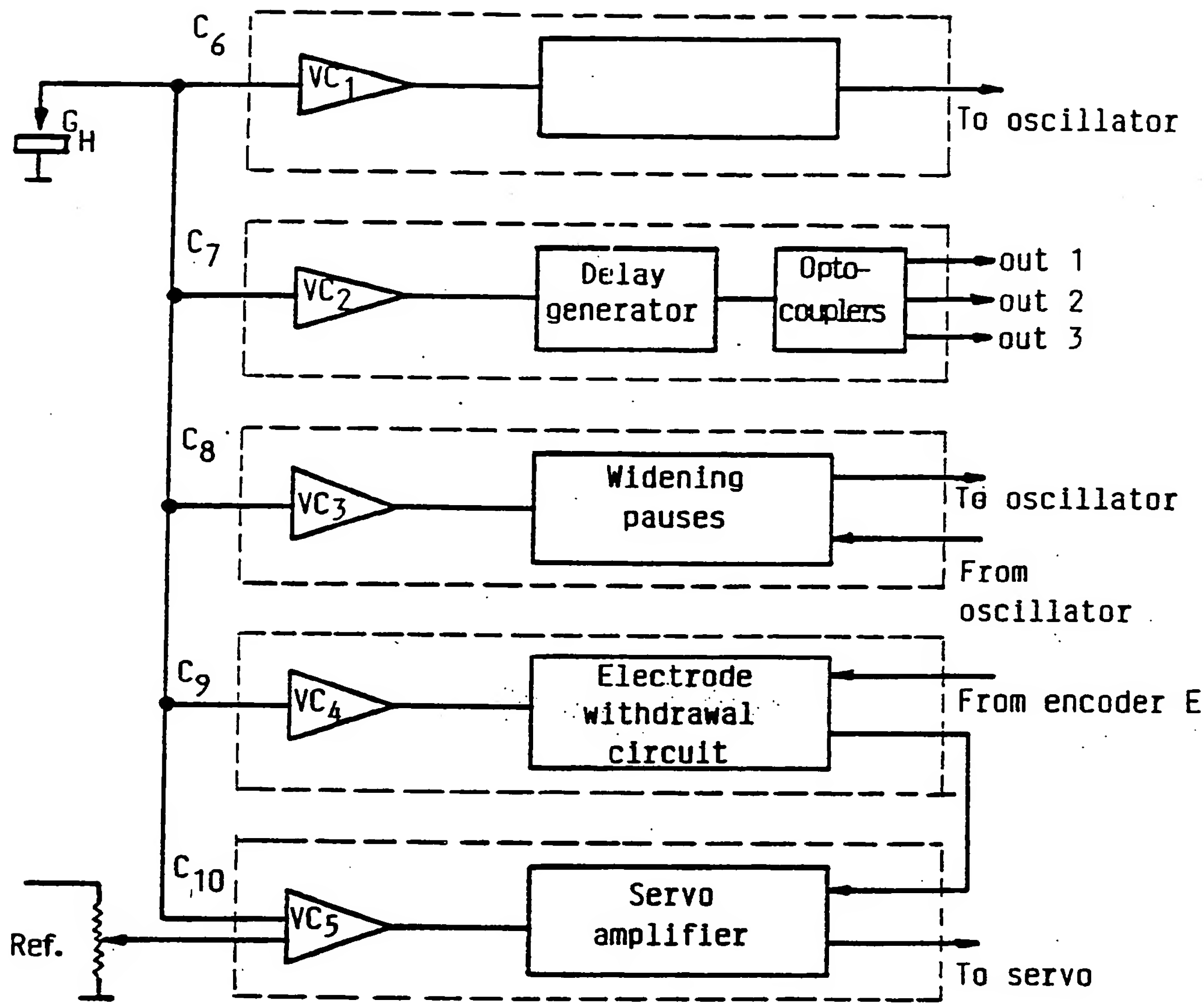


FIG. 5



C6
VC1
G
H
To oscillator
C7
VC2
Delay generator
Opto-couplers
out 1
out 2
out 3
C8
VC3
Widening pauses
To oscillator
From oscillator
C9
VC4
Electrode withdrawal circuit
From encoder E
C10
VC5
Servo amplifier
Ref.
To servo

FIG. 6

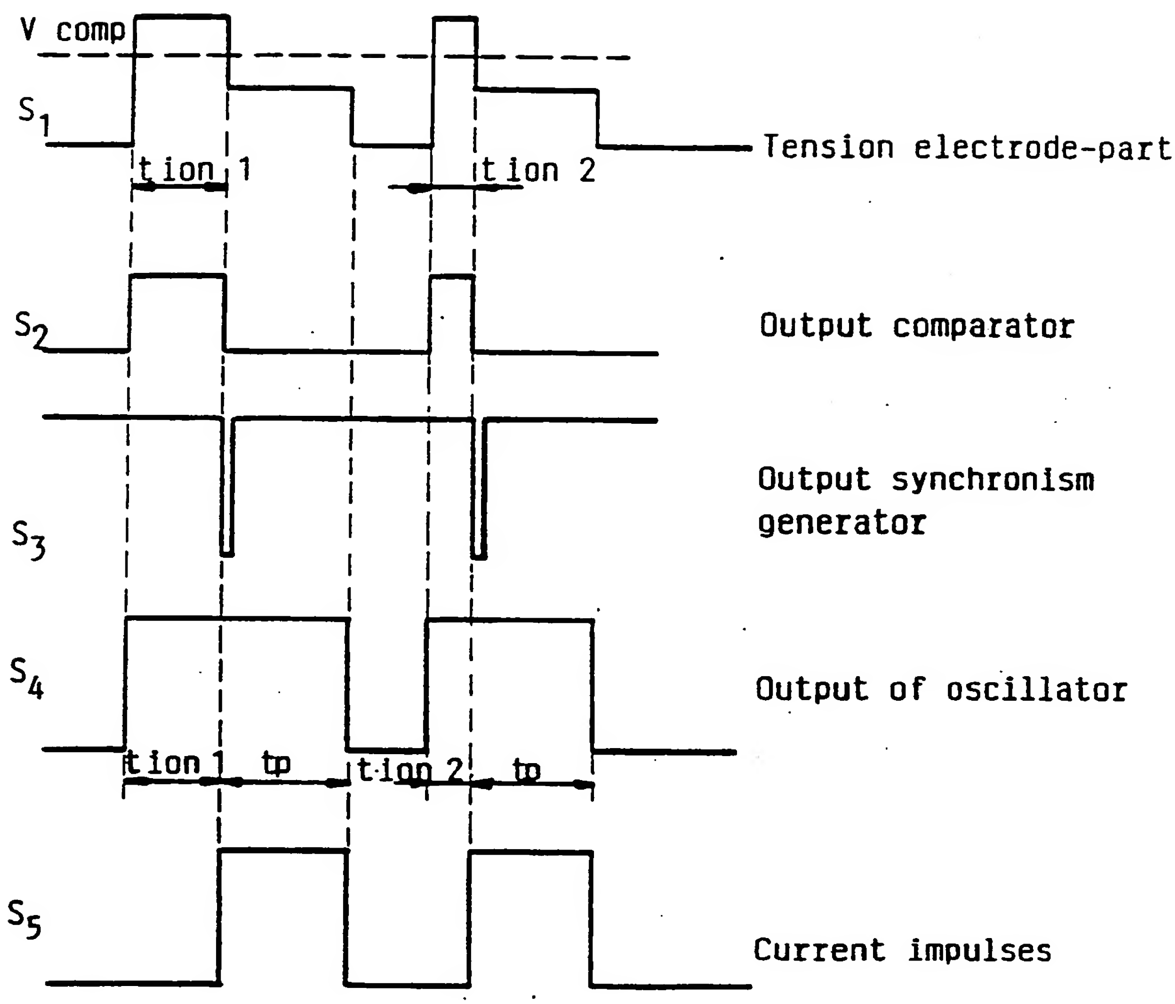

V comp
S1
Tension electrode-part
t ion 1
t ion 2
S2
Output comparator
S3
Output synchronism generator
S4
Output of oscillator
t ion 1
tp
t ion 2
tp
S5
Current impulses

FIG. 7

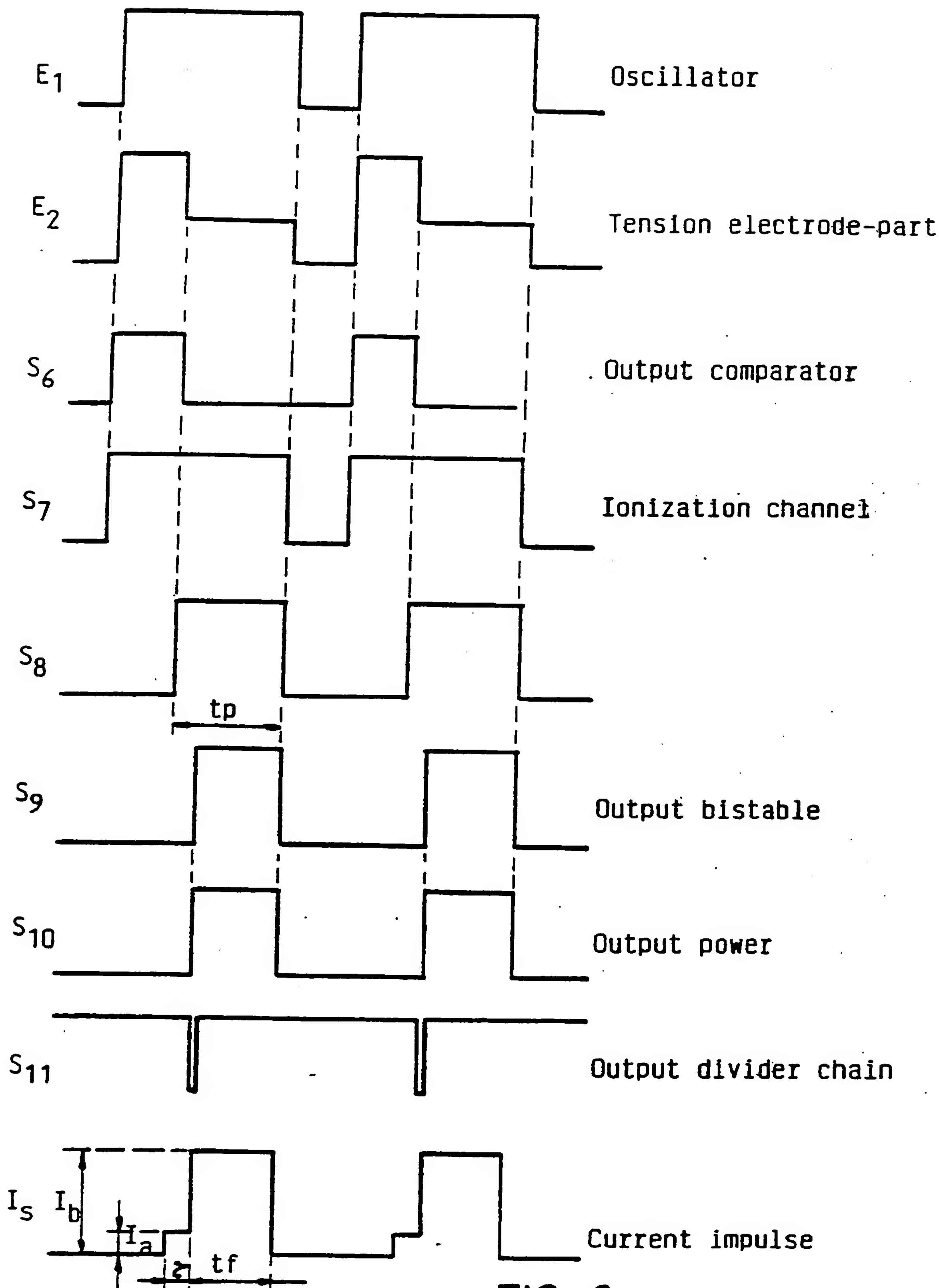

E1
Oscillator
E2
Tension electrode-part
S6
Output comparator
S7
Ionization channel
S8
tp
S9
Output bistable
S10
Output power
S11
Output divider chain
Is
Ib
Ia
tf
Current impulse

FIG. 8

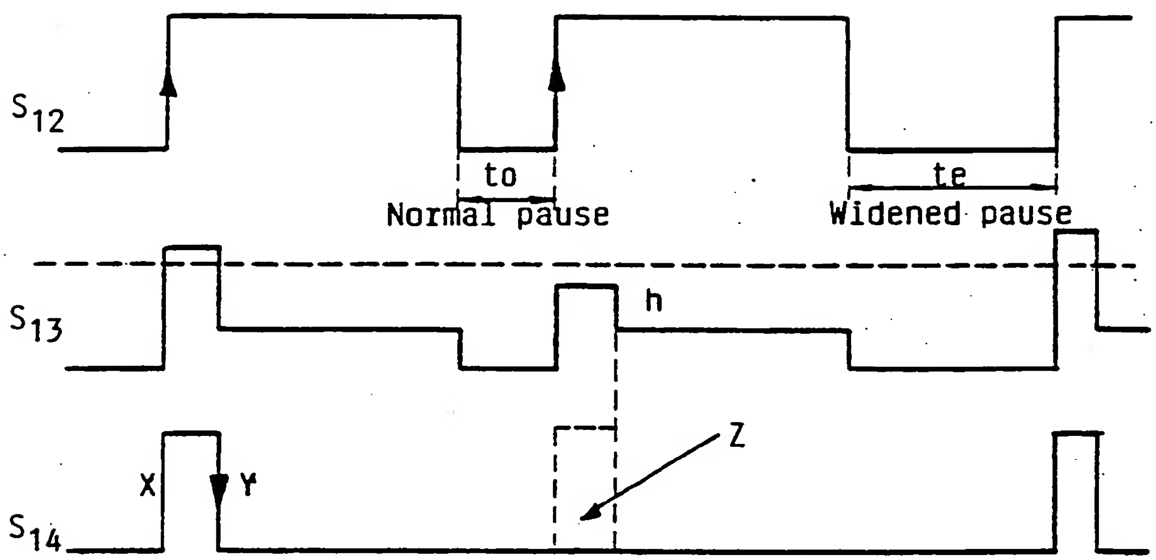


FIG. 9

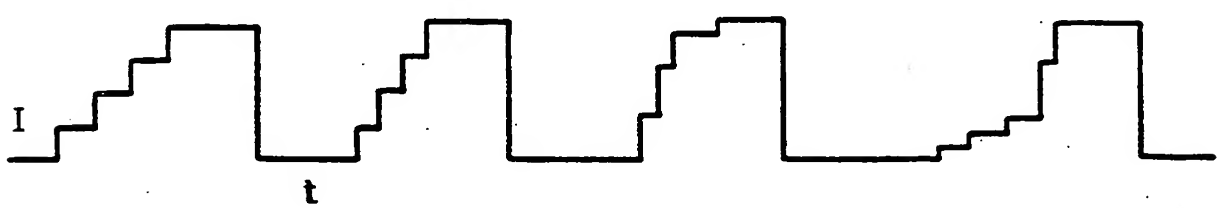


FIG. 10

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 87 0179

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X A	EP-A-52197 (FRIERDICH DECKEL AG) * page 2, line 25 - page 3, line 13 * * page 4, lines 3 - 20 * * page 5, line 28 - page 6, line 8 * ---	1 2, 4, 5	B23H1/02
X A	US-A-3974357 (MITSUBISHI DENKI KK) * column 2, lines 11 - 26 * * column 5, line 33 - column 6, line 59 * * column 8, line 38 - column 9, line 7 * ---	1-4 7	
A	FR-A-2571285 (AMADA CO) * claim 1 * ---	8, 9	
A	GB-A-2163277 (AMADA CO) * page 2, lines 9 - 59 * -----	13, 14	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B23H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	26 FEBRUARY 1990	DAILLOUX C.

CATEGORY OF CITED DOCUMENTS

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E : earlier patent document, but published on, or after the filing date
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& : member of the same patent family, corresponding document

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